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Quarterly Progress Report

Q-A2415-11

# STUDY OF ELECTROMAGNETIC TECHNIQUES FOR SPACE NAVIGATION

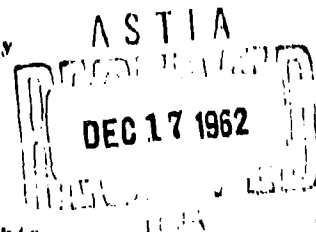
by

R. G. Franklin  
R. H. Field

August 16, 1962 to November 15, 1962

Navigation and Guidance Laboratory  
Contract AF 33(616)-7244  
Project No. 0(616)-4427

Aeronautical Systems Division  
United States Air Force  
Wright-Patterson Air Force Base, Ohio



**THE FRANKLIN INSTITUTE • *Laboratories for Research and Development***

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ABSTRACT

The stellar spectrograph has been assembled and aligned during the preceding quarter. A brief description of the mechanical construction and of the alignment procedures is given. Figures illustrate the various parts of the instrument.

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## I. INTRODUCTION

During the past quarter fabrication of the stellar spectrograph, except for the temperature control facility, was completed. The preliminary optical alignment revealed no major problems. Consequently, the instrument has been mounted in position on the vertical solar telescope in the laboratory. It is hoped that the time and funds yet remaining will allow sufficient solar data to be acquired to permit an evaluation of the design modifications incorporated in this new instrument. Of particular importance is the template vibrator which was designed to permit operation outside the range of terrestrial atmospheric effects, thus reducing the noise environment. The structural details of the spectrograph are summarized in the following report. Not all of the features described are important for operation within the laboratory. The mounting, rigidity of construction, and temperature control facilities will assume their proper importance when the spectrograph is employed with the Franklin Institute twenty-four inch reflector, the telescope for which it was specifically designed.

## II. THE SPECTROGRAPH CONSTRUCTION

The procedures followed in the design and construction of the stellar spectrograph were controlled by a number of important factors. Following the decision to mount the assembly at the Cassegrainian focus of the twenty-four inch reflector telescope, consideration had to be given to a structure of minimum size and weight that would accommodate all necessary components and maintain structural stiffness in all positions of operation. Temperature effects were also of prime importance.

In the design finally adopted, the optical bench frame is made of welded aluminum in a bridge type form to realize the greatest rigidity. The two main spans that establish the optical reference path

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are secured by strategically placed gussets in an angular (30° included angle) position. This reduces the width of the frame at the point where it is cantilever supported from the stainless steel telescope mounting ring.

The entire instrument is enclosed in a temperature controlled, light-tight housing that is also secured to the mounting ring in a cantilever fashion. In other words, the internal apparatus is completely divorced and isolated from the enclosure and any outside temperature effects.

A temperature of 100°F was chosen for spectrograph environment in order to minimize ambient variation effects and to maintain a dry internal atmosphere. All entrance and exit ports for the light are closed by lenses, thus reducing air convection currents within the spectrograph. However, certain controls are made available on the outside for convenient adjustment. These are

1. Fine adjustment for focusing grating-lens assembly
2. Slit width adjustment
3. Dual rotating plate adjustment (fine and coarse)
4. Slit slide control to adjust exposed length of slit and to act as a shutter
5. Standard source mirror
6. Template lateral adjustment
7. Auxiliary lens focus adjustment
8. Slit observation periscope.

One additional access chamber is provided to permit the introduction of the photographic plate cartridge and the vibrator template cartridge. Precise positioning of these units is mandatory since both



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cartridges must assume the same critical location whenever they are installed.

The photographic plate cartridge was designed to be loaded in a dark room. A control rod at the top is pushed in to open a light-tight hatch cover and eject a plate holder assembly. The sensitive plate is installed, and the control returned to its full out position, thus pulling the loaded holder into the cartridge and closing the hatch. The unit is plugged into the access chamber and reopened as for loading. The plate holder can be detented through three positions in respect to the light beam. Thus, three exposures can be made on each plate.

The vibration template assembly consists of two opposed electromagnetic force coils oscillating in push-pull to drive the template holder in a linear axial motion. The Alnico ring magnets are mounted on a U shaped frame that is dovetailed to the plate on the bottom of the cartridge. The template holder is suspended between two .015" thick stainless steel diaphragms that are also secured to the frame. Aluminum coil bobbins are fastened to the other side of each diaphragm and extend into the magnet radial air gap.

The optimum frequency of vibration for the proposed stellar tests is 500 cps or higher. Thus, the spring rate of the combined diaphragms was chosen to have a resonance of at least 500 cps when driving a mass that included the template holder, two coil bobbins and the glass template with hold-down springs. The present combination has a sharp resonant frequency of 600 cps with a clean sinusoidal wave form. Maximum excursion is approximately .008 inch. Further evaluation indicated little or no apparent hysteresis when checked with a Lissajous pattern. The coils are driven by an audio oscillator.

A lateral adjustment is provided on the cover plate so that the entire vibration assembly can be moved across the incoming spectrum band to achieve the best match point. This is accomplished with a

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microdial that drives through a reduction gear box and in turn rotates a constant velocity spring loaded cam. Vernier motion in the order of .0001 inch per digit is possible in either direction provided gear box backlash has been eliminated by back rotation.

Figures 1 to 10 are photographs of the instrument and its various components. Figure 1 shows the internal assembly of the instrument together with the photographic plate and vibrator assembly cartridges which are not mounted. The instrument rests on the telescope mounting ring. More detail of the various parts is shown in subsequent figures.

Figure 2 is a view of the top of the instrument showing the optical frame with the telescope mounting ring which is to be attached to the telescope frame. Inside the ring the movable mirror (in an open position) controlled by the external knob can be seen. When closed, this mirror deflects light from the standard source at the right into the spectrograph. At the top of the picture is the eyepiece for the slit viewing periscope. This can also be used to project an image of the slit onto a screen for inspection if desired.

Figure 3 shows the mounting chamber for the interchangeable photographic plate and vibrator assembly cartridges, which are shown on either side of the frame. The grating-lens assembly with its focus adjustment is shown at the left and the photomultiplier tube at the right. The collector lens, which insures that all light from the template reaches the phototube can be seen within the open chamber. This lens is behind the template when the latter is in position. Just in front of the collector lens, but not visible in the photograph, is the negative spectrum widener lens.

Figure 4 is similar to Figure 3 except that the vibrator assembly cartridge is in place in the chamber. The lateral adjustment control knob is shown at the top of the cartridge.

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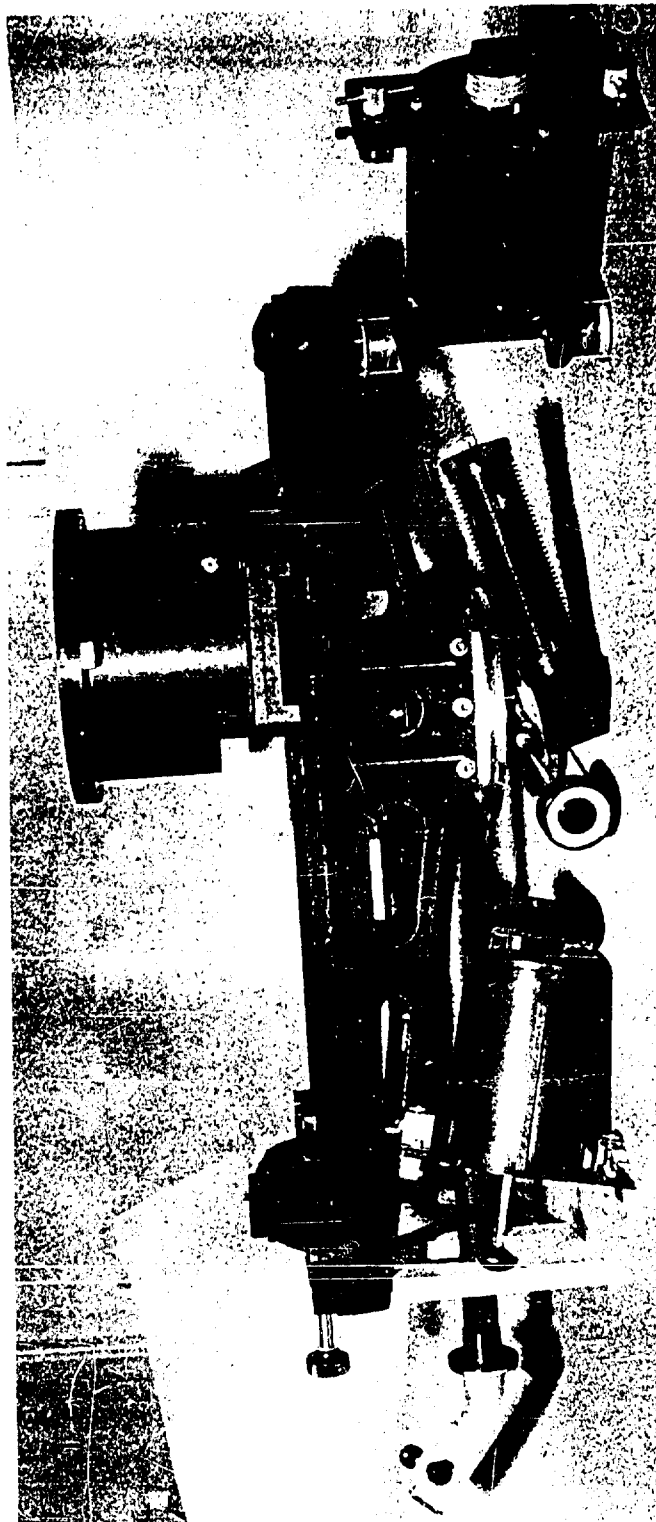


Fig. 1 - Internal Assembly of the Stellar Spectrograph Together with the  
Photographic Plate and Vibrator Assembly Cartridges

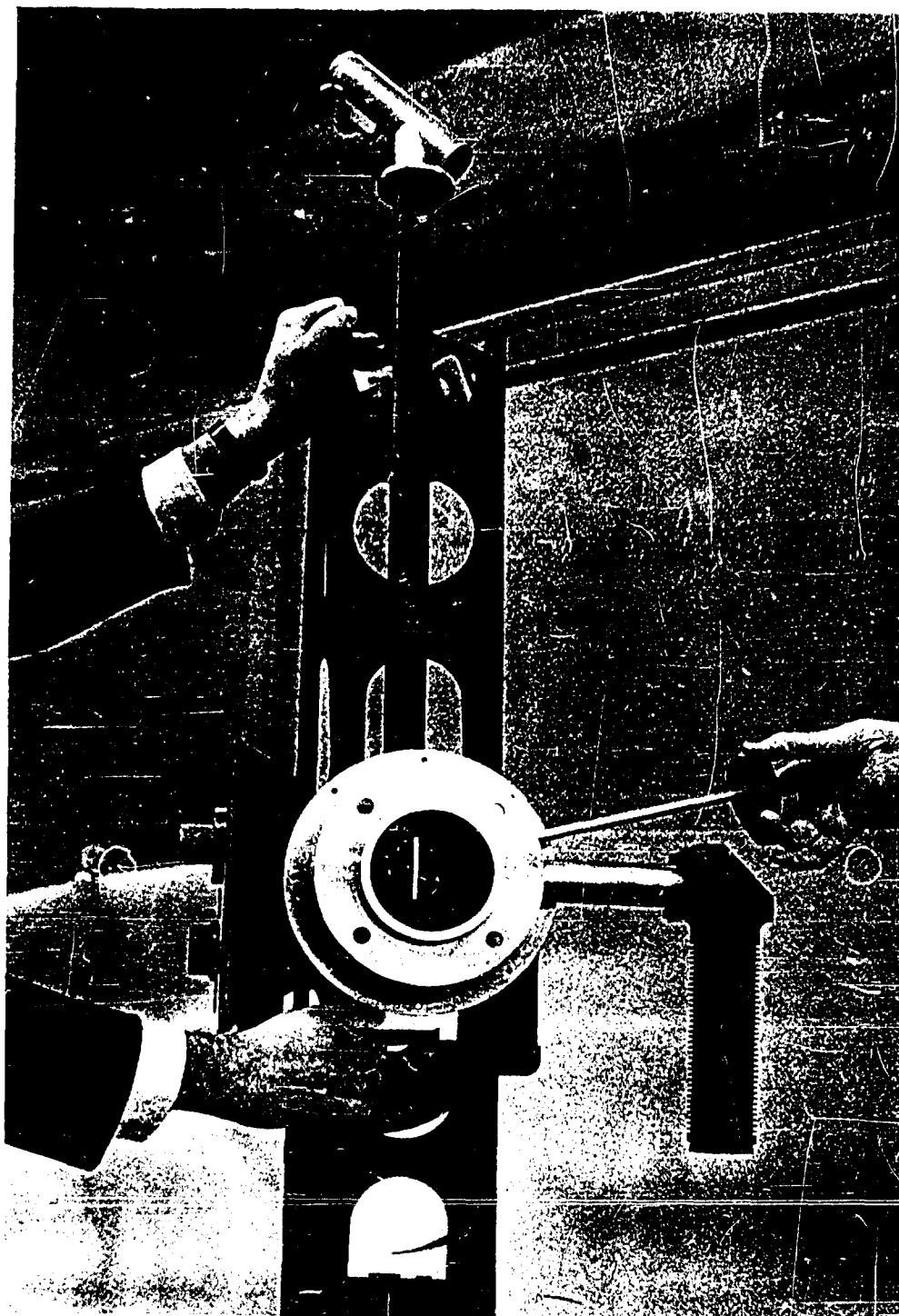


Fig. 2 - Top View of Stellar Spectrograph

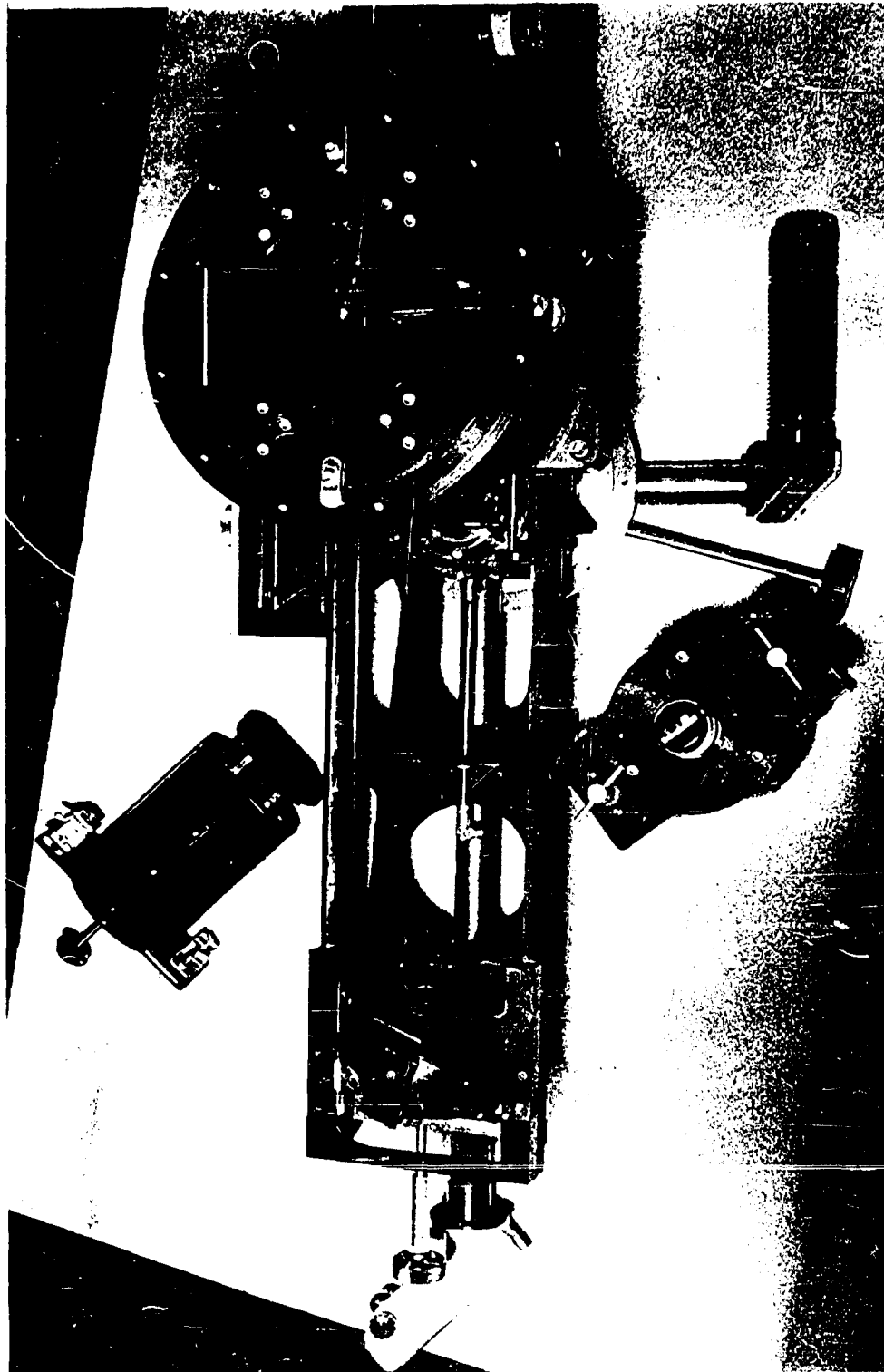


Fig. 3 - Bottom View of Stellar Spectrograph with the Cartridges Removed

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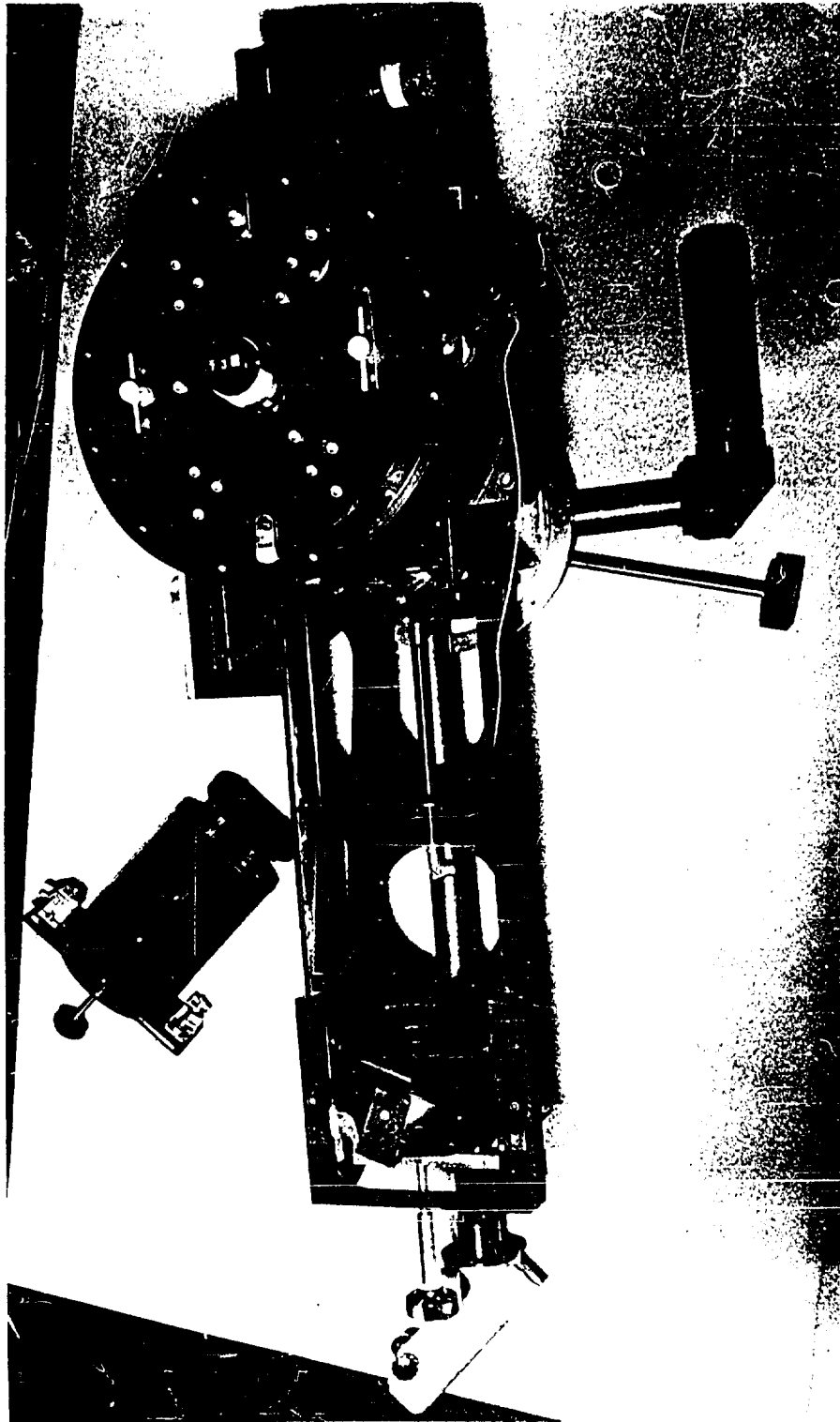


Fig. 4 - Bottom View of Stellar Spectrograph with the Vibrator Assembly  
Cartridge in Place

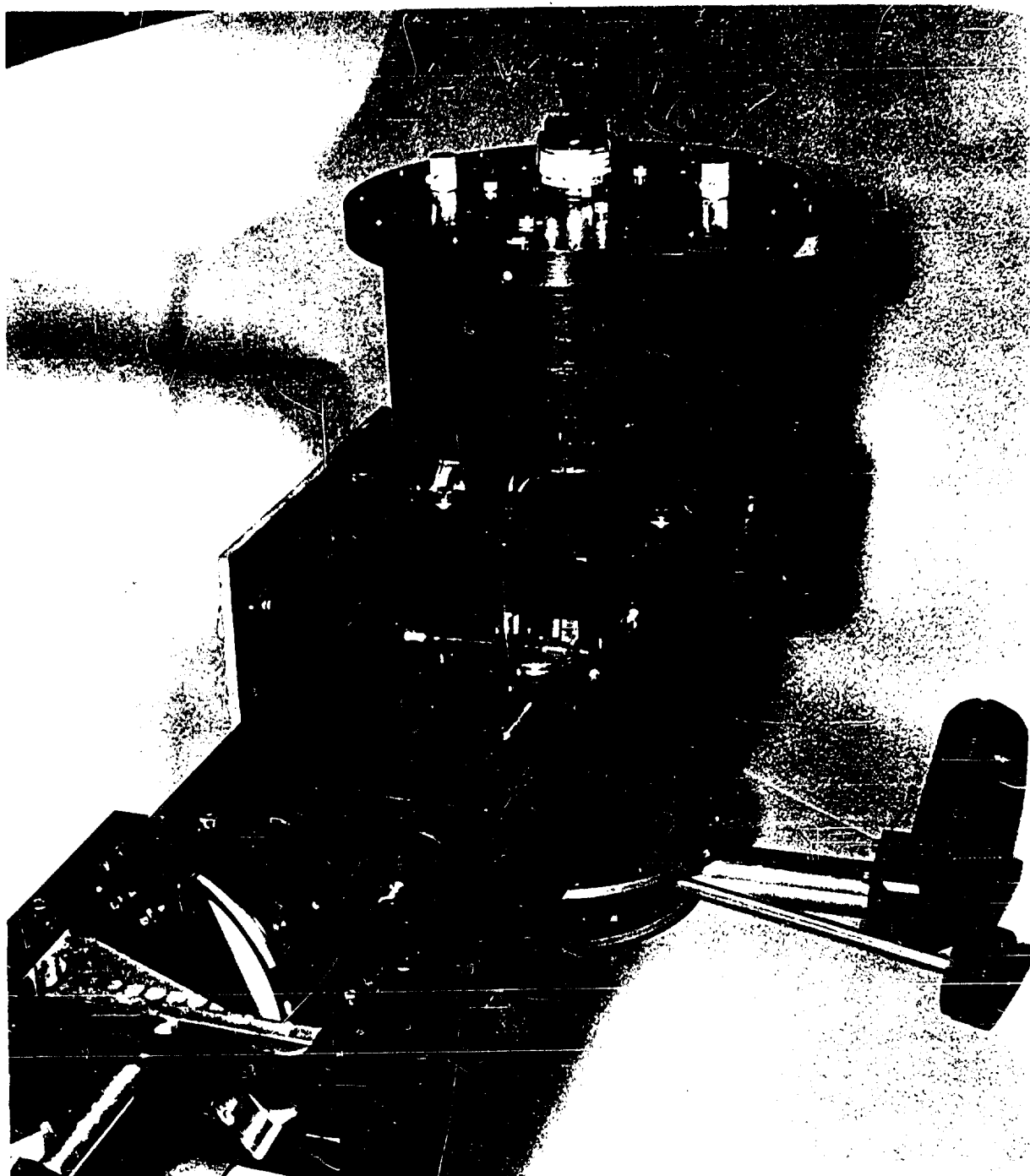


Fig. 5 - Stellar Spectrograph from the Lens-Grating Assembly End

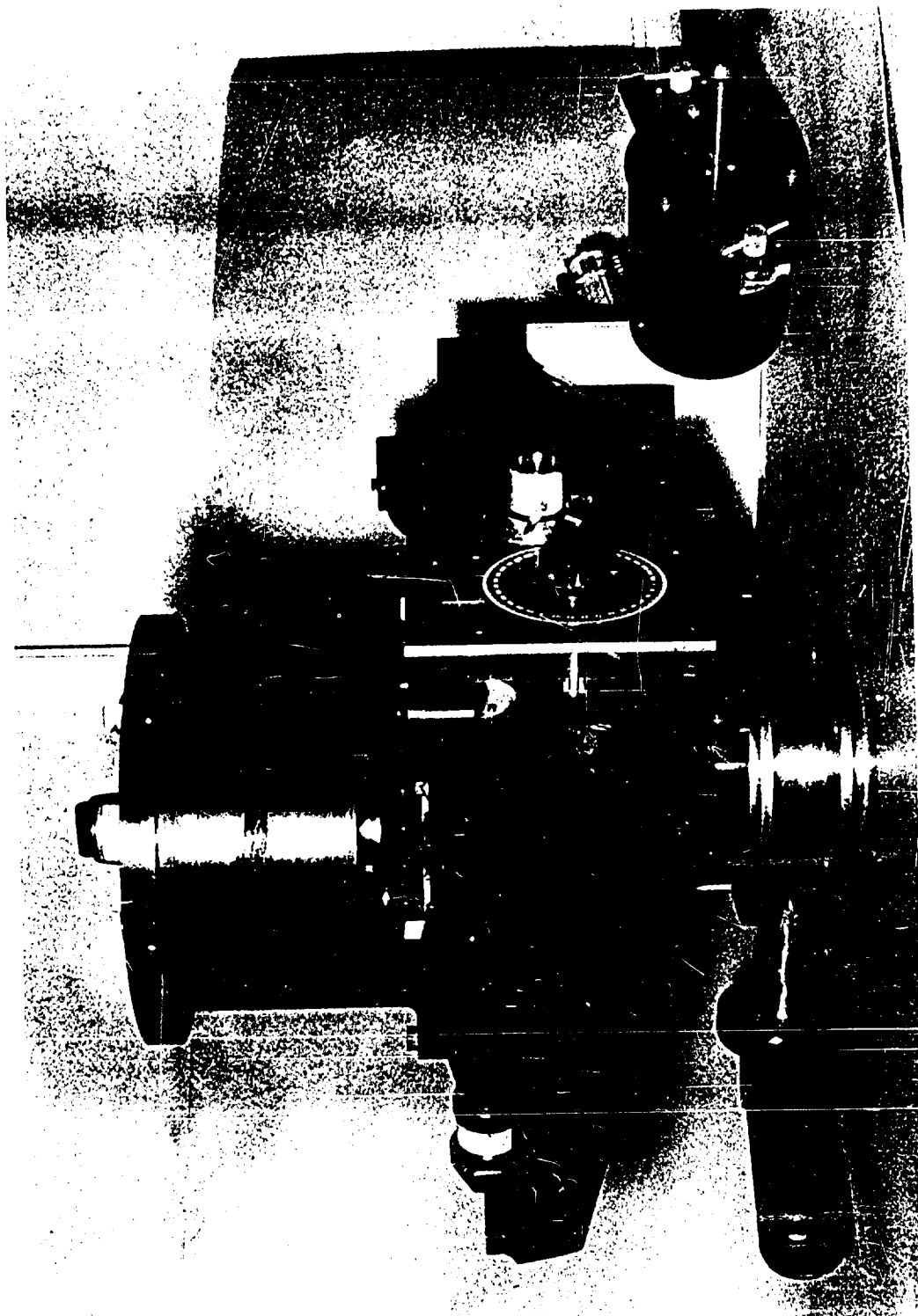


Fig. 6 - Side View of Stellar Spectrograph Showing the Control Panel



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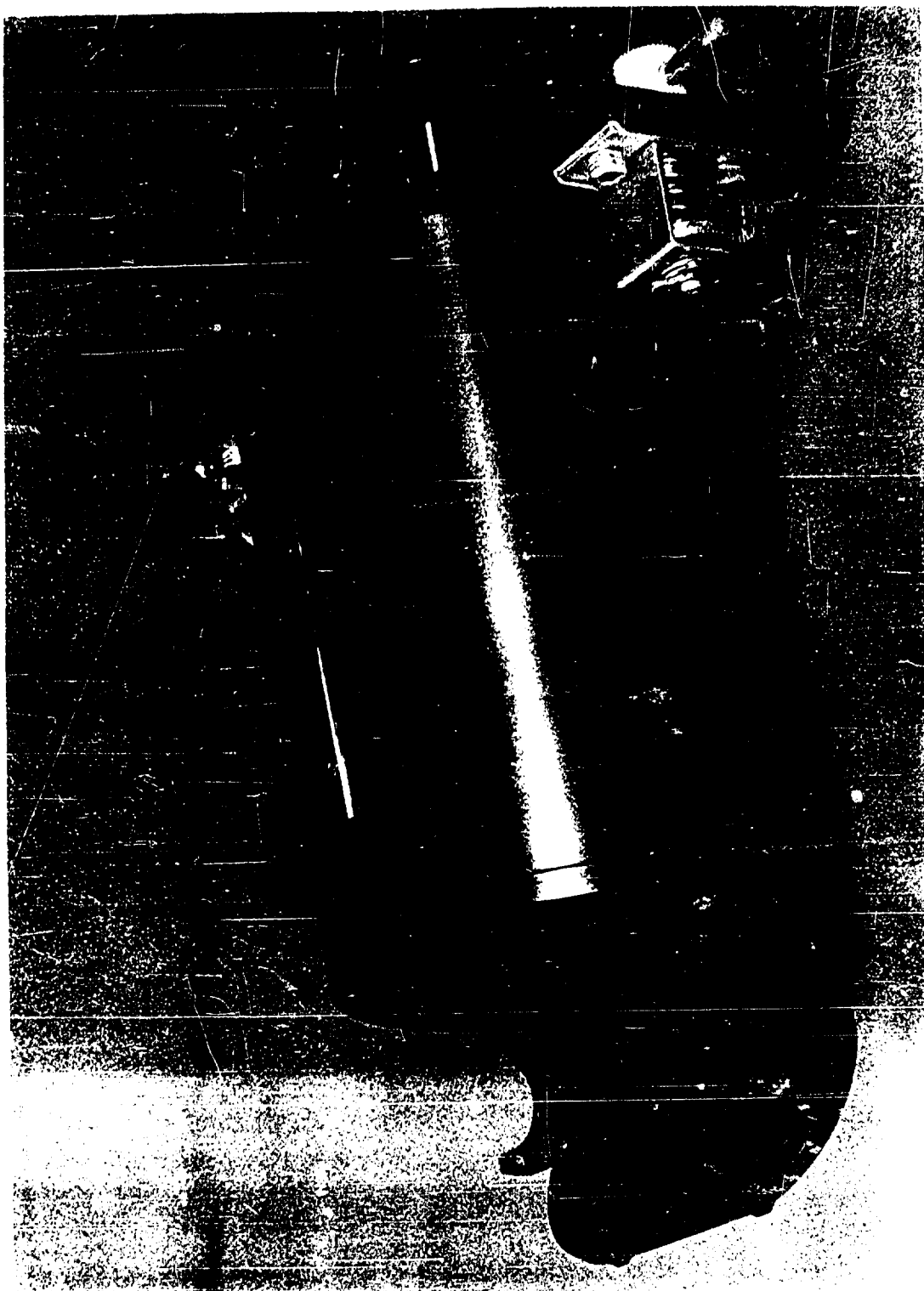


Fig. 7 - Photograph Plate Cartridge

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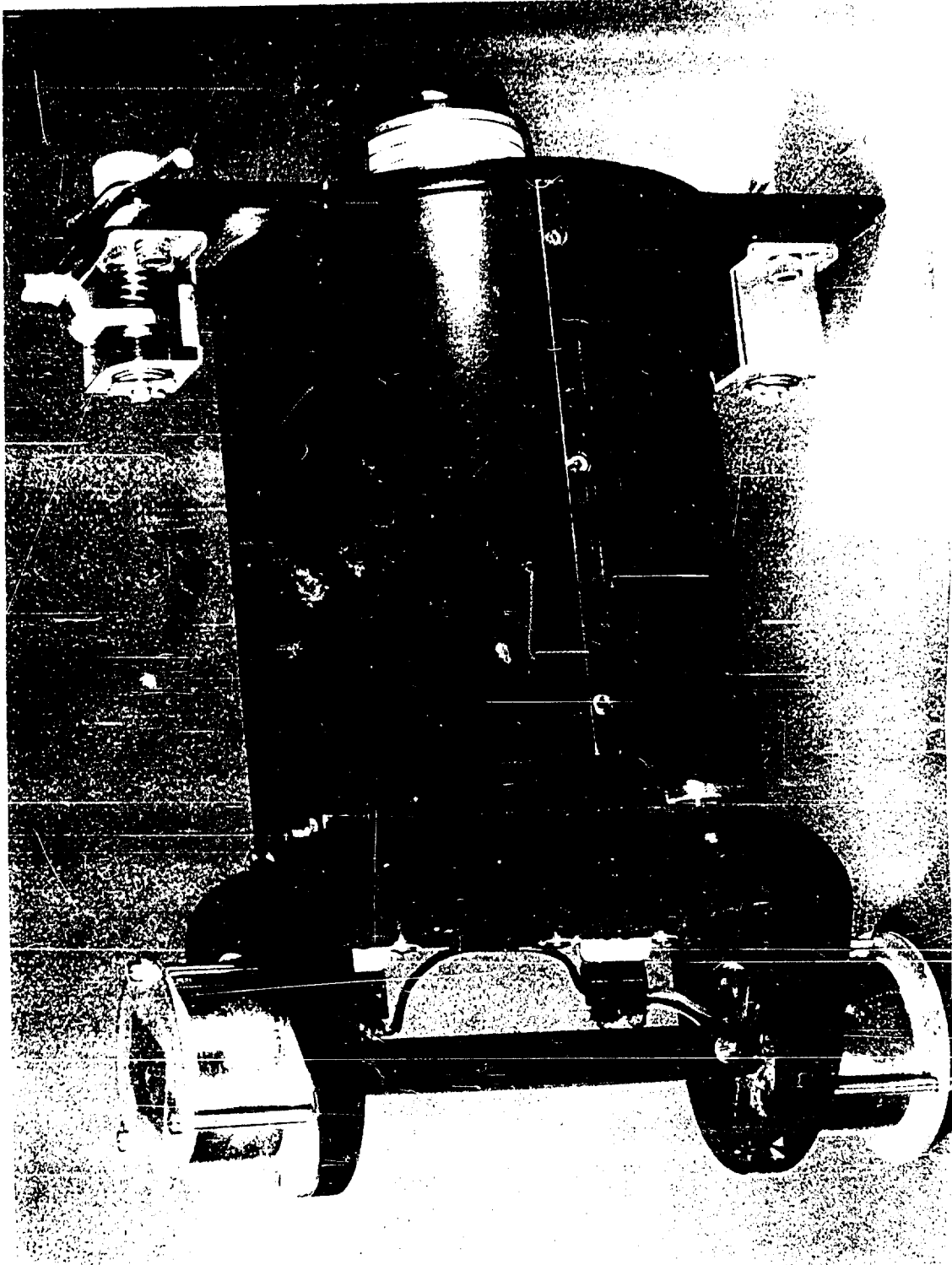


Fig. 8 - Vibrator Assembly Cartridge

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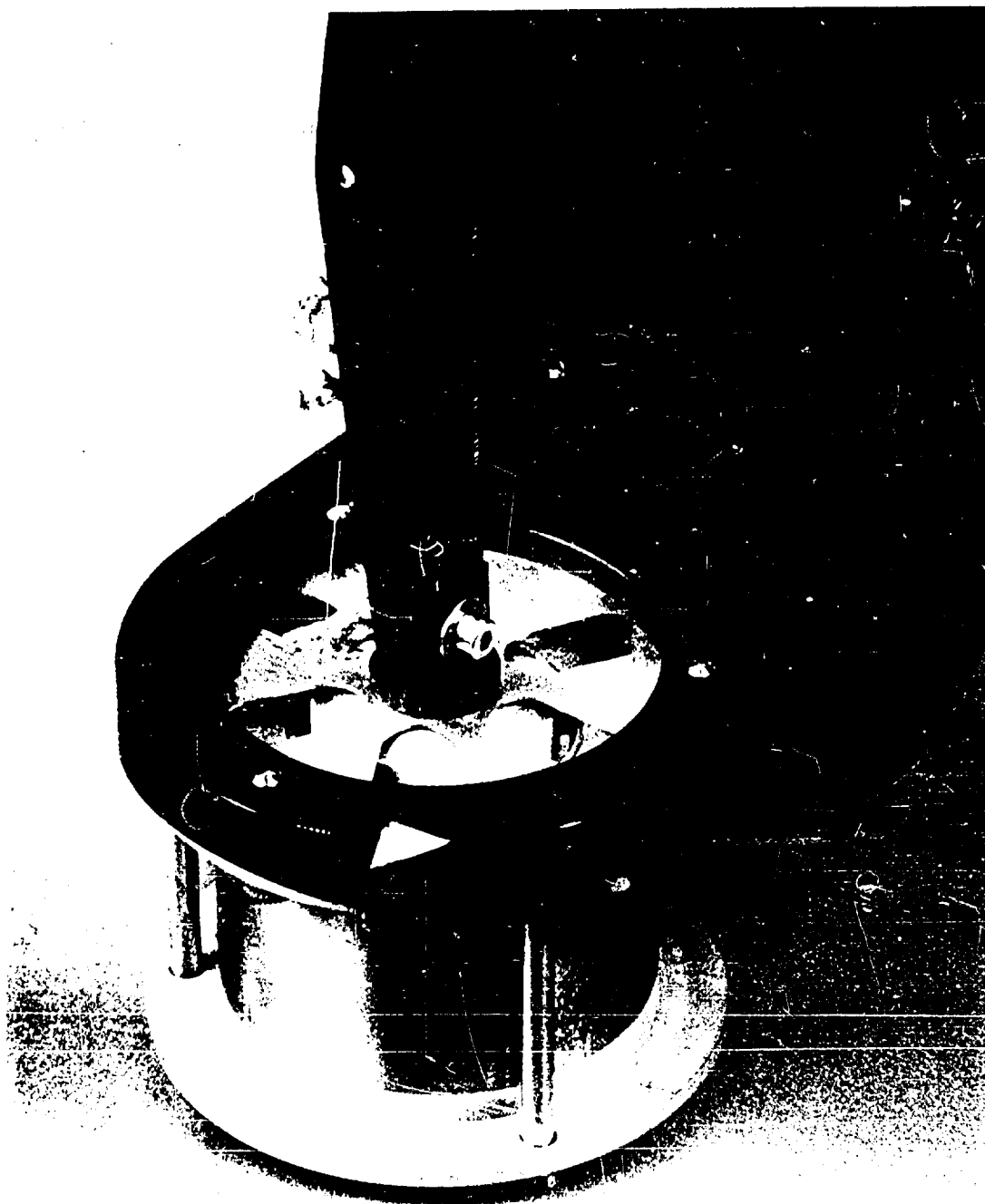


Fig. 9 - Vibrator Assembly Showing One Electromagnetic Force Coil

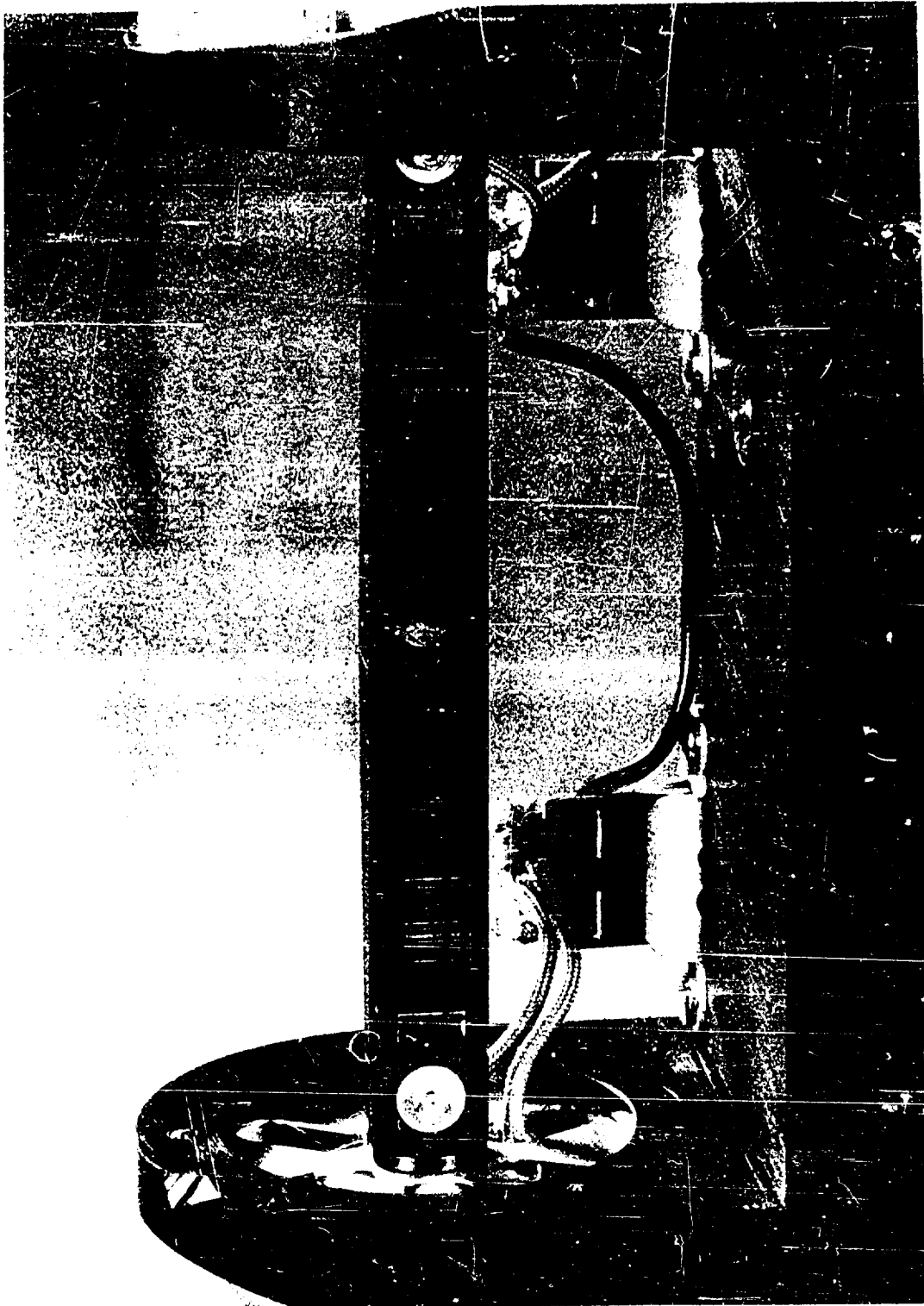


Fig. 10 - Vibrator Assembly, Template Position

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Figure 5 shows more detail of the optical bench and parts. Light from the telescope is deflected by a mirror (not visible in the figure) to the lens-grating assembly at the lower left. In the center of the picture below the light baffle one of the quartz deflector plates is shown with its worm drive control.

In Figure 6 the external controls for the quartz deflector plates are shown. The coarse control on the right has steps producing rotation of the plate of  $1^\circ$  each. The fine control is a dial divided into  $360^\circ$ . One complete turn of the dial produces two minutes of rotation of the plate.

Figure 7 is a close-up of the photographic cartridge in an open position to show the plate holder.

Close-ups of the vibrator assembly cartridge with template are shown in Figures 8, 9 and 10.

Figure 11 is a view of the whole assembly in its temperature controlled light-tight box, attached to the solar telescope in the laboratory. The control panel may be seen with the coarse and fine adjustments of deflector plates and the slit slide control. At the top of the instrument is the periscope used in this case to project an image of the slit onto a screen (not shown). Also at the top is the slit width control (not visible in the picture). To the left is the chamber for the photographic plate and vibrator assembly cartridges. The vibrator assembly cartridge is in place. An auxiliary lens shown at the right of the instrument was required to reduce the f/no of the system to completely fill the grating and lens. Behind the instrument, not visible in the photograph, are the standard source optics and the movable mirror control.

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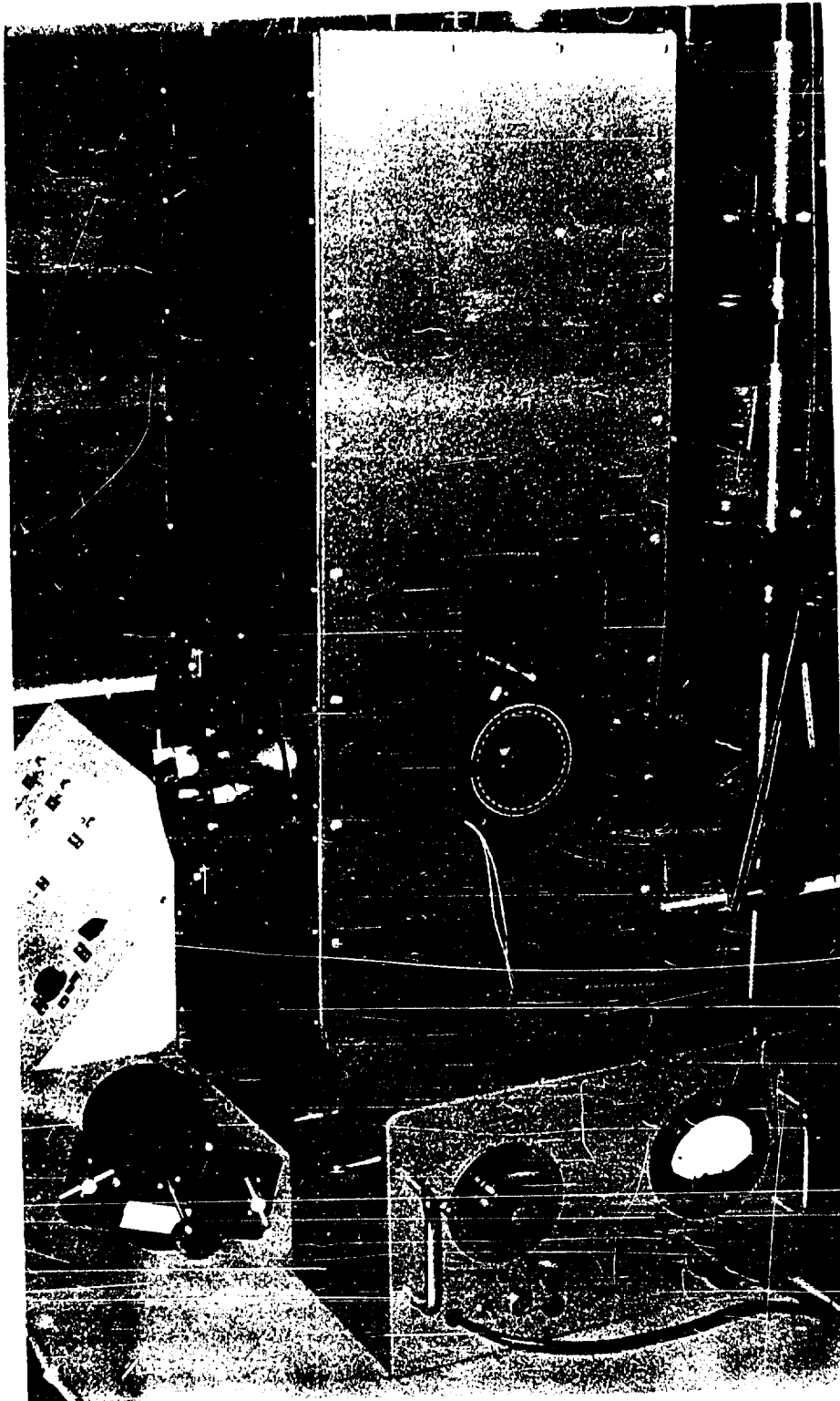


Fig. 11 - Stellar Spectrograph in Temperature Control Box Attached to the Solar Telescope

### III. ALIGNMENT OF THE SPECTROGRAPH

The alignment and adjustment of the spectrograph is a tedious procedure requiring careful testing to obtain best focus and resolution. For this work an open air iron arc source was used to illuminate the slit through the optics for the standard source. An image of the slit was projected onto a screen by the periscope so that the illumination could be monitored at all times. Preliminary focus of the lens-grating assembly was obtained by visual examination of the iron arc spectrum on a screen at the focal plane of the camera-template assemblies. The spectrograph was then placed in a light-tight box and a series of photographs of the spectrum taken. The necessary adjustments were as follows:

- a. It was found necessary to insert baffles to separate the incident and refracted beams completely to avoid fogging of the plate by scattered light. Also all reflecting surfaces which had not been anodized were given a coat of flat black paint.
- b. The lens-grating assembly was moved along the optical track by very small increments. This was done by manual rotation of the control, the displacement from a fiducial line being an indication of the setting.
- c. When that position of the lens-grating assembly which gave the best focus at the center of the spectrum plate was found, the spectrum plate was tilted with respect to the optic axis, in order to compensate for chromatic differences in focal length of the lens. This was accomplished by rotation of the photographic cartridge holder in its frame, the amount of rotation being indicated by a scale. A tilt on the order of  $1^{\circ}$  -  $2^{\circ}$  appears to be optimum.

- d. When the spectrum appeared in sharp focus throughout the wave length span of interest, the grating was rotated slightly and changes in resolution noted. This rotation also caused the spectrum lines to slant slightly away from the vertical. It was necessary, therefore, to compensate by rotation of the deflecting mirror, which in effect rotated the slit. It is necessary that the spectral lines be perpendicular to the optic axial plane, since contact prints of the iron arc plates are used as templates and any deviation from the vertical results in the crossing of the spectral lines and the template lines. The lines were carefully checked for such a deviation.

As would be expected these adjustments are interrelated. It was necessary, therefore, to recheck the focus and tilt after the grating was rotated. These operations were repeated until there was no further improvement and clear sharp lines were obtained. Figure 12 is a reproduction of the hollow cathode iron arc spectrum after final adjustments were complete. The plate factor was measured and found to be 10.8 A/mm. All movable parts were then locked in place.

- e. The detector optics were then aligned. The adjustment of these is not critical, it being necessary only to insure that all the light transmitted by the template falls on the sensitive area of the detector. This was done by visual inspection.

Templates were made from the negatives by contact printing, using high resolution, high contrast plates. A strip 3/8 inch wide was cut to fit the template holder. In order not to increase the weight of the templates, which are vibrated in the template holder at 500 - 600 cps, black



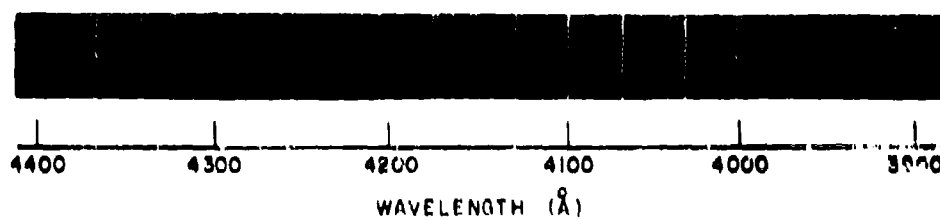


FIG. 12. HALLOW CATHODE IRON ARC SPECTRUM  
(MAGNIFICATION 3 X)

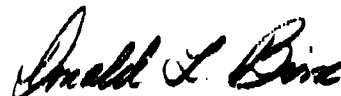
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paint was used to mask out undesirable sections of the template instead of the black masking tape previously used. However, very narrow strips of tape were applied to those parts which were difficult to paint, e.g., between rather closely spaced lines.


IV. REPORT OF TRIPS AND CONFERENCES

1. October 11, 1962, Dr. W. O. McMinn and Mr. P. D. Zenian of American Machine and Foundry Company visited The Franklin Institute to discuss the results of template spectroscopy measurements.
2. October 19, 1962, Mr. W. L. Harmon visited The Franklin Institute to discuss project status and plan future objectives.

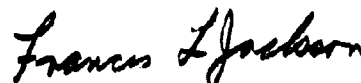


Donald L. Birx, Manager  
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